Combustion of Alcohols

Background information

The breaking of bonds is endothermic, and the making of bonds is exothermic. The difference between the two decides whether a reaction is exothermic or endothermic. We can calculate the theoretical change in energy, by using given values, of the energy required to break certain bonds.

Chemical Bond	Energy (KJ/Mol)	Chemical Bond	Energy (KJ/Mol)
C-H	413	O--O	497
O-H	464	C--O	745
C-O	358	C-C	346

Information about water

1 cm3 of water = 1g of water

Heat Transferred = Mass of Water X Temperature Rise X 4.2
(In KJ) (in Kg) (in oC)

Variables

- Type of Alcohol (Independent Variable),
- Container size/Volume of water.
- Type of container,
- The amount of carbon soot left on the container,
- Volume/Mass of alcohol,
- Time,
- Distance between wick and container,
- Tripod & gauze over stand, boss & clamp,
- Starting temperature of water.

Fair Test:

Type of Alcohol (Independent Variable):

This variable has to be the same type of alcohol, i.e. Propan-1ol , because with every carbon added in the chain after Methane, there is another place in the chain for the O-H bond to go in, or the possibility of another one added in. If the mentioned were changed, then the way and the amount of burning the chain does, changes. If the chain length was varied, then the amount of burning the chain does, changes. Note that for every one carbon added to the chain, H2 is added as well.

Container size:

The container size affects the volume of water inside it, I can't put 300cm3 of water inside a 200cm3 container. Also, if the volume of water I find most appropriate, only fills half the container, then the space not being used (and/or the larger the surface area of the water to air) will be transferring more heat to air around, than if I used the same amount of water in a smaller, more appropriate sized container.

Volume of water:
If I use too large a volume of water, then it will only heat up a small amount, allowing large inaccuracies in reading the thermometer, also there will be more heat lost due to the larger surface area to the container and/or air, and therefore less energy is saved for the temperature reading. If too little water is used, then there will be a too big increase in temperature, and the water might boil, therefore no more heat increases will be read from that point on, and all the burning alcohol will be doing is sustaining the boil, messing up 1) Time 2) Volume of water - due to evaporation 3)Volume/mass of the alcohol burnt. Also as the temperature gets so high, transfer of heat to the air will happen exponentially, and there would be a lot more evaporation, which would botch-up the equations, as being a recorded variable.

Type of container:
If copper is used, then transfer of heat into it and the water will happen quickly, but conversely heat is lost quickly out of the water into the copper and into the air, this is because the conductivity of copper is very good. If glass is used, then it will retain more heat before passing it on, thus the water will not get as much heat to start of with, than the alcohol is producing, thus giving misreading due to experimental inaccuracy, as glass is a reasonably good insulator.

The amount of carbon soot left on the container:
This affects the experiment because the carbon soot acts as an insulator and slows down the rate at which heat is transferred to the container and consequently to the water, as explained for glass in the above statement.

Volume/Mass of alcohol:
This will change because I am burning the alcohol, and the carbon and some oxygen are released as gases during alcohol combustion, as shown in the following equation:

$$2CH_3OH(l) + 3O_2(g) \quad \rightarrow \quad 2CO_2(g) + 4H_2O(aq)$$

Consequently the volume gets less, this can be used to work out how many moles were burnt, and as a result how many KJ per mole is released.

Time:
This should to be constant because you should not vary more than one thing in an experiment, but it really does not matter, as the result in the end will be the same, because the relative alcohol burnt and temperature increase, will go through the formula and produce the same result. It is like changing the voltage, through a wire, the current will change with it, but the resistance is the same.

Distance between wick and container:
This matters because, if the container is half a meter away then hardly any heat is going to get to it, but if the container is in the flame, then lots of carbon will be formed on the container (as explained earlier), and incomplete combustion will happen, thus less energy released from the same mass loss - inaccurate results.

Tripod & gauze over stand, boss & clamp: The tripod and gauze are both metal, and the gauze is in direct contact with the heat being produced, thus taking the heat away quickly, into the tripod and out into the air easily. Where as the only part of the stand, boss and clamp, in near direct heating, is the clamp, which has got rubber insulation to protect against heat exchange.

Starting temperature of water:
This should be similar all the way through, because of factors leading to evaporation of water, due to higher temperatures, and the fact that I should only change one variable at a time, but room temperature is reasonably stable, and as I am reading temperature change, so it does not really matter too much.

Plan:

Apparatus list

- Thermometer
- Water
- Alcohols
- Stand Boss Clamp
- Calorimeter
- Stand, Boss & Clamp
- Spirit Burner
- Thermometer
- Stop Clock
- Spirit Burner
- Water (300cm3)
- Measuring cylinder
- Stop Clock
- Balance

Method

1) I will set the apparatus up as shown above, setting length to 10cm.
2) Subsequently I will fill the spirit burner full of an alcohol, lets say I am testing methanol.
3) After that I will put 300cm3 of water into the calorimeter.
4) Having let the water and the calorimeter come to the same temperature, I will measure the temperature of the water.
5) I will then weigh the spirit burner and record it's weight.
6) Then I will light the spirit burner, and allow it to burn for two minutes, using the stop clock.
7) During this time the water will be stirred continuously.
8) After the burner has been put out, the time having expired, I will then measure the temperature of the water, and weigh the burner for a second time.

I will repeat the experiment with ethanol, propan-1ol, butan-1ol, pentan-1ol and hexan-1ol, and I will vary the distance between the flame and calorimeter to a get appropriate value.

I will use the calorimeter over the glass beaker because it is made of copper, which conducts heat faster, and better than glass, therefore transferring heat to water better.

I chose the stand, boss and clamp over the tripod and gauze, because the clamp has rubber over its claws, which does not conduct heat away from the calorimeter as fast as the metal gauze and tripod.

I will change the length to 5 cm because the heat is not getting transferred as well to the calorimeter as it could, and any closer, and it would be too close to the flame, so that lots of carbon would be formed on the calorimeter, preventing as much heat transfer. I will only use 100cm3 of water because we did not have available any bigger calorimeters.

Safety:
Keep lid on burners at all times, when moving and not burning. This is to prevent evaporation and the possibility of an explosion. Keep fingers, clothes and any other body parts away from burners to prevent burns.

Prediction:
The tables below show the theoretical calculation of the energy released during the combustion of alcohol. It can be seen, that if X is equal to the number of carbons in the chain, and Y is the change in energy, DH, then Y = -500.5X - 39.
In my experiment, it is not possible to anywhere near those results, or to be as accurate as those results, due to the experimental inaccuracies and limitations of apparatus, and the fact is that lots of heat will not be transferred to the water, so I would not be able to record the correct result. However it is feasible to work out the energy given out of my experiment.

If you double the number of carbons in the chain, then the energy released will approximately double. I think this is because, when the bond energy before the experiment doubles, the calculated energy released doubles, and when reacted, shorter carbon chains burn slower, because they have less hydrogen. When the carbon chain doubles, the number of carbons double, the hydrogens almost by a factor of two, and the oxygen's by two, i.e., two Hydrogen's, and three oxygens, are added, when one carbon is added. That is to say that the bond energy being broken, is increasing by 1918J every time, so you are almost going to get this doubling effect.

Results
Reading 1

Alcohol	Temperature Before (OC)	Temperature After (OC)	Temperature Difference (OC)	Mass Before (g)	Mass After (g)
Methanol	22	31	9	158.02	156.50
Ethanol	20	29	9	159.50	158.60
Propan-1-ol	23	35	12	159.50	158.55
Butan-1-ol	22	37	15	163.93	162.66
Pentan-1-ol	20	45	25	155.22	153.62
Hexan-1-ol	24	55	31	154.61	153.19

Amount of Alcohol Used (g)	How long For (Min)	Distance away from ground (cm)	Amount of Water used (g)	Joules given out (J)	Mass of 1 Mole of The Alcohol (g)
1.52	2	10	100	3.78	32
0.90	2	10	100	3.78	46
0.95	2	10	100	5.04	60
1.27	2	10	100	6.30	74
1.60	2	10	100	10.50	88
1.42	2	10	100	13.02	102

Fraction of 1M of Alcohol used	Calculated Energy Change (J)	Change in energy per mole (J/Mole)	Out BY (J/Mole)
0.04750	-539.5	-79.58	-459.92
0.01957	-1040.0	-193.20	-846.80
0.01583	-1540.5	-318.32	-1222.18
0.01716	-2041.0	-367.09	-1673.91
0.01818	-2541.5	-577.50	-1964.00
0.01392	-3042.0	-935.24	-2106.76

Reading 2

Alcohol	Temperature Before (OC)	Temperature After (OC)	Temperature Difference (OC)	Mass Before (g)	Mass After (g)
Methanol	18	29	11	149.37	147.59
Ethanol	17	30	13	158.80	157.51
Propan-1-ol	21	34	13	158.55	157.64
Butan-1-ol	20	38	18	163.33	162.22
Pentan-1-ol	17	40	23	155.70	154.49
Hexan-1-ol	16	50	34	149.40	147.51

Amount of Alcohol Used (g)	How long For (Min)	Distance away from ground (cm)	Amount of Water used (g)	Joules given out (J)	Mass of 1 Mole of The Alcohol (g)
1.78	2	10	100	4.62	32
1.29	2	10	100	5.46	46
0.91	2	10	100	5.46	60
1.11	2	10	100	7.56	74
1.21	2	10	100	9.66	88
1.89	2	10	100	14.28	102

Fraction of 1M of Alcohol used	Calculated Energy Change (J)	Change in energy per mole (J/Mole)	Out BY (J/Mole)
0.05563	-539.5	-83.06	-456.44
0.02804	-1040.0	-83.06	-845.30
0.01517	-1540.5	-360.00	-1180.50
0.01500	-2041.0	-504.00	-1537.00
0.01375	-2541.5	-702.55	-1838.95
0.01853	-3042.0	-770.67	-2271.33

Average

Average Change in energy per mole (J/Mole)
-81.3
-193.9
-339.2
-435.5
-640.0
-853.0

Graph

Graph :- Comparing The Calculated Energy Change and The Results

Analysis:

Methanol, Butan-1ol and Hexan-1ol, all seem to be slightly anomalous, but none were particularly hard readings to get. I wanted to repeat these readings but time ran out.

Conclusion:

On the previous page, gridlines have been marked on, producing the following results:

Number of Carbons in Chain	1	2	4
Reading on Line of Best Fit	-30 J/Mole	-190 J/Mole	-500 J/Mole

Number of Carbons in Chain	3	6
Reading on Line of Best Fit	-340 J/Mole	-800 J/Mole

This shows approximately the pattern of -150 times the number of carbons in the chain + 100 J/Mole. That is to say the energy released goes up by 150 J/Mole for every carbon added to the chain. This undermines my prediction, because the energy does not double every time the number of carbons in the chain doubles, it is out every time by approximately 120 J/Mole. The results show a correlation downwards as expected, but due to experimental inaccuracy, not as much as the calculated, or predicted correlation. This is probably due to the errors in this experiment explained below and the huge loss of heat between the burning alcohol and the water/thermometer:

1. Energy given off through sound and light;
2. Heat conducted and convected away through the air;
3. Radiation of heat out into the atmosphere;
4. The fact that not all the water was the same temperature;
5. Evaporation of water so there will be less water to heat, and therefore make the water hotter;
6. The fact that the calorimeter gets hot, means that not all the temperature is added to the water;
7. The rubber clamp transferred heat away;
8. Heat may be taken away through gusts of wind.
9. The fact that at higher temperatures, heat is lost faster to the air and out of the calorimeter, due to the bigger heat difference, making the higher temperatures more inaccurate, and making a shallower gradient on the graph.

All the above adds to the huge difference between the calculated energy change and the results.

Evaluation

Sources of error in this experiment include:

1. Energy given off through sound and light;
2. Heat conducted and convected away through the air, i.e. hot gasses not measured;
3. Radiation of heat out into the atmosphere;
4. The fact that the calorimeter gets hot, means that not all the temperature is added to the water;
5. The rubber clamp transferred heat away;
6. Heat may be taken away through gusts of wind;
7. The fact that at higher temperatures, heat is lost faster to the air and out of the calorimeter, due to the bigger heat difference, making the higher temperatures more inaccurate, and making a shallower gradient on the graph;
8. By incomplete combustion, shown by yellow flame & carbon soot left on copper calorimeter;
9. The amount of energy you give the alcohol originally;
10. The availability of alcohol for the wick to burn, if not enough then the wick would burn, not the alcohol, which would give an incorrect reading;
11. Evaporation of water so there will be less water to heat, and therefore make the water hotter;
12. The fact that different amounts of wick was sticking up out of the burner, which would affect the rate at which the alcohol would burn, but not an error that has a major effect;
13. The fact that not all the water was the same temperature;
14. The fact that the flame size changed, due to the specific alcohol, and the distance between the tip of the flame and the calorimeter was not the same throughout;
15. How you stop the experiment, and whether it is on time.

1-10 would decrease the reading
11-12 would increase the reading
13-15 could be either.

Correction of 1-10:
I could have started the experiment below room temperature, so that the amount of gained energy, from room temperature, might equal the energy lost at temperatures higher than room temperature.

Correction of 11-12:
I could seal the calorimeter, and move all the wicks to the same height.

Limitations of apparatus

The apparatus in this experiment is very bad, because heat is a bad way to transfer energy, without any loss of it. Any molecule, of any thing will conduct heat to a greater or lesser extent, radiation happens and can be reduced but not stopped, and the most limiting factor of this experiment is the convection of air, and to a lesser extent of water. In all the transfers of heat through the apparatus, you are giving energy to

things other than the water. The wick, air, calorimeter, thermometer, burner, the not combusted alcohol clamp, boss and stand, are all given energy that, ideally should go to the water and be kept by it. During the experiment, some water will evaporate, and so your temperature/water mass readings will change because of this, your temperature reading might go up a little bit.
The entire above paragraph with the exception of the last sentence, would decrease the readings.

Validity

Not every value of the test variable was tested, and the ones I did do need to be repeated to get better-backed results. Specifically Methanol, Butan-1ol and Hexan-1ol. This experiment would be improved if we could have used pure ethanol (drinking alcohol) apposed to methylated spirits, and perhaps if a wider range of alcohols was tested, then a better graph and graph could have been attained. Perhaps if I started the experiment below room temperature, so that the amount of gained energy, from room temperature, might equal the energy lost at temperatures higher than room temperature, then the experiment could produce better results. Another way to reduce heat loss from the water, is to use a Nutfield calorimeter, as shown on the following page, also using a bomb calorimeter is also feasible, shown on the next page.